Maritime Hazard Analysis

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Rick Wilson, California Geological Survey
Kevin Miller, California Emergency Management Agency

Partners =

[Logos of various organizations]
Tsunami Current Hazard Maps

- Harbor/marina infrastructure and maritime evacuation planning
- Emergency response planning for harbor patrol
- Guidance for harbor masters
- Fall 2011 – first CA draft maps for San Diego Bay

2011 – CGS/CalEMA/USC
Potentially damaging tsunami currents (+4 knots; in red) for San Diego area from M9.2 earthquake on eastern Aleutian Islands subduction zone
Tsunami Current Hazard Maps
Map Generation

- Example – examine Ventura Harbor, CA
- Create Maximum Current map comprehensive of all sources simulated
- Decide on bins of current-damage relationships
  - For example (not for real map use):
    - 12+ knots = widespread major damage to harbor structures, vessels of all sizes pulled from mooring lines
    - 8-12 knots = moderate damage, small vessels pulled off moorings
    - 4-8 knots = minor damage to docks
  - Using currents only does not include effects of vertical water rise/fall
    - Combine in some way with inundation maps
  - Momentum flux not a good indicator of floating structure damage
- Visual identification of “zones”
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<table>
<thead>
<tr>
<th>Harbor, Ponto, Bay, and Docks Served (from north to south)</th>
<th>Feb. 27, 2010 First Annual Times</th>
<th>Maximum Tsunami Amplitudes</th>
<th>Estimated Maximum Current Speeds (knots)</th>
<th>Reported/Damage or Other Effects from Tsunami (NDM = no damage reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crescent City</td>
<td>1340</td>
<td>0.63</td>
<td>2.47</td>
<td>20-25 MDH</td>
</tr>
<tr>
<td>Lurea</td>
<td>1336</td>
<td>0.2</td>
<td>0.97</td>
<td>NDR</td>
</tr>
<tr>
<td>Newport</td>
<td>1334</td>
<td>0.1</td>
<td>0.10</td>
<td>15-20 NDR</td>
</tr>
<tr>
<td>Anacapa</td>
<td>1261</td>
<td>0.49</td>
<td>1.76</td>
<td>NDR</td>
</tr>
<tr>
<td>Point Reyes</td>
<td>1259</td>
<td>0.48</td>
<td>1.35</td>
<td>NDR</td>
</tr>
<tr>
<td>Morro</td>
<td>0.66</td>
<td></td>
<td></td>
<td>NDR</td>
</tr>
<tr>
<td>Oak Bluffs</td>
<td>0.51</td>
<td></td>
<td></td>
<td>4-6 NDR</td>
</tr>
<tr>
<td>Alamosadena</td>
<td>1944</td>
<td>0.18</td>
<td>0.51</td>
<td>4-6 NDR</td>
</tr>
<tr>
<td>San Francisco</td>
<td>1320</td>
<td>0.22</td>
<td>0.82</td>
<td>7 NDR</td>
</tr>
<tr>
<td>Half Moon Bay</td>
<td>0.96</td>
<td>0.7</td>
<td>7-10</td>
<td>15-28 NDR</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>0.51</td>
<td>0.9</td>
<td>1-6-1.9</td>
<td>20-20 Minor damage to boats and harbor infrastructure</td>
</tr>
<tr>
<td>Moss Landing</td>
<td>0.3</td>
<td>2</td>
<td>15-25</td>
<td>200+ pils damaged (51.84m)</td>
</tr>
<tr>
<td>Morro Bay</td>
<td>1231</td>
<td>0.45</td>
<td>0.3</td>
<td>2-9-7 NDR</td>
</tr>
<tr>
<td>Port San Luis</td>
<td>0.82</td>
<td>0.3</td>
<td>1.6</td>
<td>13-20 NDR</td>
</tr>
<tr>
<td>Point Loma</td>
<td>0.84</td>
<td>0.8</td>
<td>2.02</td>
<td>5 NDR</td>
</tr>
<tr>
<td>Point Vicente</td>
<td>2.43</td>
<td>0.6-1.2</td>
<td>0.7-1.0</td>
<td>NDR</td>
</tr>
<tr>
<td>Santa Barbara</td>
<td>1230</td>
<td>0.75</td>
<td>0.82</td>
<td>8-10 10-20 Minor damage to floating equipment</td>
</tr>
<tr>
<td>Ventura</td>
<td>0.6-6.9</td>
<td>1.3</td>
<td>12-15 10-15</td>
<td>Damage to dock and number of boats destroyed (13.49)</td>
</tr>
<tr>
<td>Detroit</td>
<td>1.0</td>
<td>0.9-1.2</td>
<td>2-3</td>
<td>9-10 Minor damage to docks</td>
</tr>
<tr>
<td>Long Beach</td>
<td>1235</td>
<td>0.77</td>
<td>0.42</td>
<td>4-6 Minor damage to docks and marine infrastructure</td>
</tr>
<tr>
<td>Marina del Rey</td>
<td>2.1</td>
<td>0.6-1.0</td>
<td>0.49</td>
<td>Minor damage to docks and marine infrastructure</td>
</tr>
<tr>
<td>Two Harbors/Catalina</td>
<td>1215</td>
<td>0.77</td>
<td>0.42</td>
<td>4-6 Minor damage to docks and marine infrastructure</td>
</tr>
<tr>
<td>Long Beach</td>
<td>1215</td>
<td>0.77</td>
<td>0.42</td>
<td>4-6 Minor damage to docks and marine infrastructure</td>
</tr>
<tr>
<td>Sunset</td>
<td>0.3-0.6</td>
<td></td>
<td></td>
<td>NDR</td>
</tr>
<tr>
<td>Huntington</td>
<td>0.72</td>
<td>5-8</td>
<td>9-10</td>
<td>Minor damage to docks and boats</td>
</tr>
<tr>
<td>Newport</td>
<td>0.5</td>
<td>0.3</td>
<td>8-10</td>
<td>5 NDR</td>
</tr>
<tr>
<td>Dada Point</td>
<td>0.5-0.7</td>
<td>0.6</td>
<td>10-15 10-15</td>
<td>Minor damage to boats</td>
</tr>
<tr>
<td>Deserted</td>
<td>0.6</td>
<td>0.5</td>
<td>5-10</td>
<td>4-6 Minor damage, several boats carried to sea, boat trailer swamped</td>
</tr>
<tr>
<td>La Solana</td>
<td>1.202</td>
<td>0.84</td>
<td>0.60</td>
<td>0.19</td>
</tr>
<tr>
<td>Mission Bay</td>
<td>0.8-10</td>
<td>0.8-10</td>
<td></td>
<td>NDM</td>
</tr>
<tr>
<td>North Shelter Island, San Diego Bay</td>
<td>0.6-1.2</td>
<td>0.3-1.2</td>
<td>12-15-7-8</td>
<td>Moderate damage to docks, concrete piers, and boats</td>
</tr>
<tr>
<td>Cabrillo Island, San Diego Bay</td>
<td>0-3.6</td>
<td></td>
<td></td>
<td>NDM</td>
</tr>
<tr>
<td>Miramar, Condominium, San Diego Bay</td>
<td>0.4</td>
<td></td>
<td></td>
<td>NDM</td>
</tr>
<tr>
<td>Navy Point, San Diego Bay</td>
<td>1204</td>
<td>0.27</td>
<td>0.40</td>
<td>0.6-0.6</td>
</tr>
<tr>
<td>National City, San Diego Bay</td>
<td>0.3-0.6</td>
<td></td>
<td></td>
<td>Minor damage to docks and boats</td>
</tr>
</tbody>
</table>

Table 1: Recorded and observed measurements and damage estimates in California from the February 27, 2010 and March 11, 2011 tsunami. Current speed estimates may be overvalued because of inexperience of observers. Blank cells indicate that data was not collected for those locations; they do not represent zero values. Red boxes associated with photos to the left.
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• Example – examine Ventura Harbor, CA

• Create Time-Threshold Map
  • Time-threshold = time interval between arrival of initial wave to a later time after which current does not exceed a given value (threshold)

• For example:
  • 8 knot threshold map

• Allow for an estimation of how long until location is “safe”

• Useful for showing maximum possible duration of damaging tsunami effects

• A more difficult piece of information to convey

“safe” after 2 hours

“safe” after 4 hours
Offshore Safety Zones

- “Rule of thumb” for safety is 100 fathoms
- This is likely to be highly conservative in general
- Offshore safe zone should be controlled by expected offshore currents
  - What is a “safe” offshore tsunami current?
- Zones will be harbor/boat specific and included in navigational charts
- Statewide Guidance for Advisory and Warning events
March 11, 2011:
- Warning, then Advisory
- Largest tidal fluctuations
- $20M in damages
- 9 month delays in recovery

Work update
- Collected and reviewing 30+ videos from 2010 and 2011 events
- Evaluation of currents from videos complete
- Analysis of sediment scour/deposition complete
- Interviews with harbor master
- Preliminary modeling complete
March 11, 2011:
- Warning, then Advisory
- Strong surges and large bores
- $28M in damages
- 9 month delays in dredging

Work update
- Collected and reviewing 90+ videos from 2010 and 2011 events
- Evaluation of sediment scour/deposition complete
- Preliminary review of currents from 2010 and 2011 events complete
- Interview with harbor master
- Contracts on modeling moving forward

March 11, 2011 severe bores causing damage to docks and boats in upper Santa Cruz Harbor
Recent tsunamis:
- Advisory during 2010 and 2011
- Strong surges but in different areas in 2010 and 2011
- $500k in 2010 damages
- Multiple issues with recreational boaters

Work update
- CGS at harbor during 2011 event
- Collected and reviewing 20+ videos from 2010 and 2011 events
- Evaluation of currents has begun
- Contracts on modeling moving forward
Port of LA/LB Pilot Area

- **Recent tsunamis:**
  - Advisory during 2010 and 2011
  - Moderate surges in 2010 and 2011
  - Minimal damage
  - Multiple issues with large vessel traffic in both Ports

- **Work update**
  - Collected and reviewing 30+ videos from 2010 and 2011 events
  - Evaluation of currents has begun
  - Preliminary modeling underway
  - Collaborating and leveraging work with USGS SAFRR Project
  - Formal briefing with Ports complete

2012– USGS/CGS/CalEMA/USC
Shelter Island (SD Bay) Pilot Area

- **Recent tsunamis:**
  - Advisory during 2010 and 2011
  - Strong surges in 2010 and 2011
  - Damage to docks and boats in different areas of Island

- **Work update**
  - Collected and reviewing 30+ videos from 2010 and 2011 events
  - Evaluation of currents has begun
  - Preliminary modeling finished (earlier map)
  - Working with Seismic Safety Commission, Navy, and Port
  - Formal briefing with Navy/Ports complete

**February 27, 2010 – North Shelter Island dock damaged**

**March 11, 2011 – South Shelter Island boat sunk**
Several types of boating communities (different size ships and levels of experience):
- Recreational
- Commercial/Fishing
- Large transport/cruise ships/military

Policy group forming
- Planning issues
- Recovery issues

Guidance for harbor masters and boaters needed
- Advisory and Warning events

Brochures for boaters (right)
Tsunami Current Hazard Maps

Difficulties in Modeling Currents

• Strongest currents can be due to confined jets and large eddies
  • Models need to be able to capture these features
  • Current-based benchmarking?

• Should NOT expect currents under a tsunami to have a uniform vertical profile
  • Bottom shear (friction) will lead to a sheared (log-law) profile, with shear rate related to bottom stress (roughness)
  • Surface currents can be much larger (50+%) than depth-averaged currents. Effect is greatest at time of max currents
  • Model predictions should include this correction in some way

• Tides?
• Long duration simulations?
